THE EFFECTS OF SIRE LINE, SLAUGHTER WEIGHT, AND GENDER ON PORK QUALITY AND YIELD CHARACTERISTICS

by

HALEY GILLELAND

(Under the Direction of T. Dean Pringle)

ABSTRACT

Lean yield line (LYL) and meat quality line (MQL) boars were mated to PIC C-42 females to determine the effects of sire line, slaughter endpoint, and sex on carcass quality and yield characteristics. Three pigs within a litter and gender category were randomly assigned to slaughter weights of 113, 136, and 159 kg. Results indicate greater marbling for the MQL compared to the LYL, but the LYL had tenderness advantages compared to the MQL. Consistent advantages in lean yield existed in the LYL compared to the MQL. Increasing slaughter weight increased the pounds of boneless cuts; however, due to fat accumulation, increasing slaughter weight negatively impacted lean yield for both lines. No quality differences were found as carcass weight increased; however the MQL carcasses had greater marbling scores than the LYL. Advantages in meat quality were not as consistent across sire lines as were advantages in yield.

INDEX WORDS: Genetics, Carcass Yield, Pork Quality, Slaughter Weight

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DEDICATION

First and foremost, I would like to dedicate this thesis to the glory of God. The desire to continue my education, the sanctification that came with many bumps along the way, the patience and strength to persevere, and the reminder that I am to "work heartily" as I am "working for The Lord and not for human masters" (Colossians 3:23) have all come because of the supernatural work of Christ in me.

I would also like to dedicate this work to my family, especially the Sloans, who instilled in me an appreciation for agriculture and livestock production at a young age. Visits to Grandpa's farm in Missouri and getting to show Cody and Troy's pigs and sheep in the county fairs got me started young. I'm so thankful to them as well as Uncle Scott, who helped us get started showing pigs when I was able to join 4-H myself. I would love to say it was my own hard work and dedication that allowed me to excel not only in the show arena but in my 4-H project work with pork production. However, that would be doing a strong disservice to my parents. To my mom- thank you for embodying what hard work looks like, for teaching me the right way to do things and not letting me settle for less than my best. Thank you for all of your guidance and for reminding me there's always room to make my best even better. To my dad- thank you for your patience with me and for helping to make pig chores a family affair at our home. And to Jenna and Justin- I will forever cherish the memories of working hogs, taking care of each others' pigs just as much if not more than our own, rooting for each other at the shows, and getting to compete together at State 4-H Congress – valuable time spent not just as siblings but actual friends. I love you all.

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CHAPTER 1

INTRODUCTION

The swine industry has placed a premium on lean growth in order to meet growing demand for lean, affordable pork products. Increased pork supply has come in large part from increases in market weights, as hog numbers have fluctuated in response to feed prices and health issues like the porcine epidemic diarrhea virus. At the same time, growing global demand for pork as well as increased penetration of pork into the foodservice trade has led to emphasis on genetic lines of pigs that produce high quality pork products. As the pork industry continues to grow, it is important to understand how market weight impacts carcass value in lines of pigs selected for lean growth, as well as those selected primarily for quality. Thus, this study is designed to determine the effect of slaughter weight on carcass composition and meat quality attributes of a lean yield and meat quality boar lines mated to PIC C-42 females.

CHAPTER 2

LITERATURE REVIEW

According to the Pork Checkoff 2016 Report, 23 percent of protein sold in food service was pork (National Pork Board, 2016). Pork is considered the fastest growing protein in food service and has retained this title for the past six years (National Pork Board, 2016). The rise in demand for pork in the foodservice industry has caused an increased demand for higher quality pork that attributes to an overall better eating experience as flavor, juiciness, and tenderness are optimized. This has led to a need for research into production animals that have the genetic propensity to produce carcasses that excel in meat quality (Lonergan et al., 2001; National Pork Board, 2016).

The retail meats industry is placing emphasis on two different pork markets: commodity vs. value-added (Mabry and Baas, 2001). Pork accounted for 31 percent of protein sales in grocery stores (National Pork Board, 2016). Commodity pork, or what one would find in a traditional grocery store, is based on what a typical consumer would look for in raw pork products: “very lean with a consistent color and little purge” (Mabry and Baas, 2001). Producing the highest quantity of muscle tissue has been a goal for the industry for a long time, and merit buying programs have increased the desire for producers to raise these traditional animals (Lonergan et al., 2001). The priority placed on leanness has caused a reduced eating quality (Moon et al., 2003; Newcom et al., 2005; Wiseman et al., 2007). Therefore, swine producers today can choose the high lean growth side or more contemporary sire lines that excel in meat quality, both of which have their advantages.

Merit buying programs for carcass cutability have caused a shift to optimum leanness, and this in turn has affected meat quality (Mabry and Baas, 2001). Today's pork is leaner than pork just 20 years ago. With the study of genetic selection and lean tissue development, less fat and greater lean for pork carcasses has resulted, along with faster growth rates of the animals (Wiseman et al., 2007). These improvements in feed and growth efficiency, and information on the relationship between lean growth and meat quality have greatly influenced the swine industry.

POSTMORTEM CHANGES AND MEAT QUALITY

There are various factors that affect pork quality, which are interrelated, including marbling, pH, water holding capacity, and color (Mabry and Baas, 2001). It is important to take into account when desiring to change or improve a certain quality attribute, that quality traits are composite traits and are influenced by genetics as well as antemortem and postmortem factors (Huff-Lonergan et al., 2002). Understanding the influencers of these quality measures is vital to the progression of pork quality in the swine industry.

After slaughter, a carcass goes through many postmortem changes as it is converted from muscle to meat, including temperature and pH declines. These changes can affect many processing characteristics, such as binding, cooking losses, and emulsifying capacity (Miller, 2011; Aberle et al., 2012). Once the animal is dead, muscle cells shift from aerobic processes to anaerobic processes, and adenosine triphosphate stores are no longer able to break the myosin and actin bonds (Bate-Smith and Bendall, 1949; Bendall, 1960; Savell, 2005). Because of the decline in ATP production, the sarcoplasmic reticulum loses the ability to sequester calcium, cytoplasmic calcium levels increase, and cross bridges are formed by the muscle proteins (Bate-Smith and Bendall, 1949; Bendall, 1960). In addition, the onset phase of rigor mortis starts.

Lactic acid is produced as a byproduct of the anaerobic metabolism of glycogen, and because of the addition of H+ to the sarcoplasm, pH starts to decline (Frisby et al., 2005; Savell, 2005; Aberle et al., 2012; Scheffler et al., 2013). These positively charged ions will bind to the negatively charged amino acids and change the environment as the repulsive forces of the dissociated amino acid side groups that were helping the muscle maintain its solubility lessen (Bate-Smith and Bendall, 1949; Bendall, 1960; Aberle et al., 2012). Overtime, the pH will decline from 7.0 to 5.5 in normal muscle (Savell, 2005; Huff-Lonergan, 2010; Miller, 2011; Scheffler et al., 2013).

The rate of pH decline in muscle postmortem as well as the extent very much affects pork quality (Scheffler and Gerrard, 2007). Chilling conditions, muscle enzyme activity, rate of chilling, use of electrical stimulation, handling prior to slaughter, and length of time on kill floor can all cause the pH to drop below the optimum level and have economically damaging effects to the meat due to a decrease in meat quality (Scheffler and Gerrard, 2007). Small changes in pH can cause drastic affects on water holding capacity (Hamm, 1960). The pale, soft, and exudative condition, known as PSE, is common in pork where animals were put under short-term stress prior to slaughter (ie. electrical prods). This causes the pH to start declining faster while the carcass temperature is still high. This leads to lower water holding capacity and excessive protein denaturation (Frisby et al., 2005; Scheffler and Gerrard, 2007; Aberle et al., 2012). In addition, PSE pork is discriminated against at the retail counter due to the pale, pink color associated with it (Warner, 1997; Scheffler et al., 2013).

Less common in the pork industry but still seen in red meat is the presence of dark, firm, and dry (DFD) carcasses. The DFD condition occurs when the pH of meat is greater than 5.9 (Miller, 2011). This can be caused by long-term stressors, as glycogen supply is depleted before

slaughter; therefore, there is less lactic acid production in the muscle at death (Bendall, 1960; Warner, 1997; Miller, 2011). Pork from these carcasses is seen as too dark for consumers to purchase, but this condition is rarely seen in pork (Scheffler et al., 2013).

As pH declines postmortem, protein denaturation starts to occur, and the ability of meat to retain moisture decreases (Bendall, 1960; Warriss, 2000). This quality characteristic, called water holding capacity, affects raw meat attributes like texture and firmness as well as the cooked meat attributes of tenderness and juiciness. Water holding capacity is important because meat with a low water holding capacity can lack juiciness and not have as enjoyable eating experience for consumers (Warriss, 2000; Miller, 2011). During storage, shrinkage of the meat product increases as water holding capacity decreases as the natural moisture of the meat is released into the packaging as purge (Miller, 2011; Aberle et. al, 2012).

Water makes up 75 percent of muscle, and once animals are harvested, the water, which is located between the muscle cells and muscle bundles, is allowed to move around more freely (Bendall, 1960; Hamm 1960). This type is called immobilized water, and is most prone to leaving the muscle post rigor (Frisby et al., 2005; Huff-Lonergan, 2010; Aberle et al., 2012). This exudation on average contains about 112 mg of protein per milliliter and is made up of primarily myoglobin and water, but glycolytic enzymes and vitamins are also found in it. Purge has a greater chance of leaving the muscle as pH decreases (Huff-Lonergan, 2010; Aberle et. al, 2012). The other two types of water located in meat are bound and free water. Bound water has reduced mobility and undergoes very little changes during the conversion of muscle to meat as well as during processing because these dipolar molecules are bound very tightly to the proteins' electrically reactive groups (Hamm, 1960). Because of this, the amount of bound water in meat changes very little. On the opposite end of the spectrum is free water. This water becomes

available whenever a force is applied to the meat, and is very weakly bound to muscle (Huff-Lonergan, 2010; Aberle et. al, 2012).

COLOR

Not only are pH and temperature correlated, but color is affected by pH as well. Ultimate pH (pHu) varies among muscles, and muscles with a darker red color will generally have a higher pH. While the isoelectric point is on average 5.0-5.4, and muscles with a higher red fiber content, such as the gluteus medius, will normally have a pH closer to 6.0 (Warriss, 2007).

Desirable pork color has a pinkish-red lean and white adipose. This is the first thing consumers see in packages of fresh pork. The National Pork Producer's Council uses a scale on fresh loin surfaces from 1 to 6, with 1 being very pale and 6 being darkish red, with the optimum color being 4. Visual assessment of color using the human eye is subjective, which led to the need for developing instruments that can more accurately and consistently describe color (Berg, 2000; Aberle et al., 2012).

Colorimeters are often used as objective tools to measure meat color. Different tissues reflect and transmit light differently, and when light is transmitted onto meat it is able to provide color information about the tissue (Whitman et al., 1996).

The Hunter colorimeter is widely used, and gives an L*, a*, and b* value. This scale determines color within a three-dimensional space. L* measures lightness, and a lower L* value means a darker tint. Red to green is measured with a*, and b* measures blue to yellow (Whitman et al., 1996). The human eye views images in red, green, or blue, so these instruments are helpful in determining a human's perception of color. The L* value 43 corresponds with the NPPC color score 4 (Berg, 2000). On a six point scale, the NPPC's optimal target for color is 3.0-5.0 (Berg, 2000). Some packing plants sort cuts based on visual color, to determine the best marketing

options for the cuts, however, the use of objective measurements to sort in packing plants are not currently plausible since pork carcasses are not ribbed (Berg, 2000; Aberle et al., 2012).

The impact of meat color is seen in the retail case, as consumers will shy away from pork cuts that are seen as too pale (L*= 61) or too dark (L*= 31) (See and Belstra, 2003). These purchasing decisions are often seen when dealing with retail cuts such as loin chops where the lean is exposed in the package. In addition to the reddish-pink desired pork, uniform color in hams has become an important topic in the meats industry.

Variability in ham color can negatively affect consumers' purchasing decisions for hams. A study by See and Belstra (2003) sought to study the degree of variation in ham color for the gluteus medius, quadriceps femoris, and psoas major muscles among 259 carcasses. Hams were visually classified by color as normal, slightly two-toned, moderately two-toned, and two-toned/ PSE. Fluid loss, pH, and Minolta L* values were measured. They found that pigs with higher lean content tended to have decreased color uniformity in the ham face. For the quadriceps femoris and gluteus medius muscles, "ultimate pH decreased linearly and Minolta L* value and fluid loss percentage linearly increased with decreasing uniformity of color in the ham face." However, there were no significant differences in psoas major (See and Belstra, 2003).

Another study by McKeith and Pringle (2013) evaluated the quality differences in two-toned hams vs. control hams. Results showed that two-toned hams had higher L* values, and pH and color from the gluteus medius were highly correlated with L* values. In addition, purge loss was different between the two ham groups, with the two-toned hams having a higher purge loss than the control group (McKeith and Pringle, 2013).

TENDERNESS

Palatability greatly influences repurchasing decisions for consumers (Mabry and Baas, 2001). In sensory panels, palatability is measured by juiciness, tenderness, and flavor. All of these characteristics are correlated to the important meat quality attributes of color, tenderness, and intramuscular fat, which can be greatly influenced by postmortem factors as well as genotype (Warriss, 2007; Aberle et al., 2012).

Meat tenderness is affected by many different factors, both ante and post mortem, and consumer perception of tenderness is difficult to study. Consumer responses often denote it as the most important factor in likeability of the overall eating experience (Dilger et al., 2010). During mastication perception of meat is defined as softness to tongue and cheek, resistance to tooth pressure, ease of fragmentation, adhesion, and residue after chewing (Greaser, 1997).

Genetics, age at slaughter, sex, and muscle location all affect muscle tenderness. Studies on tenderness have shown not only differences among varying breeds, but also differences among sire lines within a breed (Dilger et al., 2010). The amount of collagen varies among these factors. As an animal matures and certain muscles are used more frequently for mobility, the amount of collagen, and chemical cross-linking of these fibers increases (Greaser, 1997; Dilger et al., 2010). This results in stronger adhesion during mastication because of the high amounts of collagen still in muscle even after cooking (Greaser, 1997; Aberle et al., 2012).

To determine tenderness, both subjective and objective methods have been used. Large samples sizes have caused subjective consumer panels to be more time consuming, so Warner-Bratzler shear force and slice shear force methods have been intensively shown to be accurate methods of measuring objective tenderness and have shown very high correlations with consumer tenderness measures (Shackelford and Wheeler, 2009).

Aging of meat has been observed to improve meat tenderness because of the greater protein degradation, so a 14 day aging prior to freezing is very common for these methods of objective tenderization. Dilger et al. (2010) reported a 70% shear force decrease between 2 and 7 days postmortem, with no improvements between 14 and 21 days, suggesting a plateau of optimum tenderness at 14 days.

Both slice and Warner-Bratzler shear force methods use an electronic testing machine with a blunt-end blade to shear through a core or slice perpendicular to the muscle fibers to measures the kilograms of force required to do so. According to Shackelford et al. (2004), slice shear force has advantages over Warner-Bratzler shear force because of the decrease in time and labor required per sample. The slice method is performed soon after cooking, while Warner-Bratzler is performed on samples that are cooled to 2°C. In addition, six good cores are needed to measure Warner-Bratzler, and slice shear force only requires two, reducing research costs by decreasing the labor required (Shackelford et al., 1999; 2004).

At 7 days aging, the targeted value for tenderness by the NPPC is less than 3.2 kg for Warner-Bratzler values. However, there is lack of research looking at threshold tenderness for pork, primarily due to the perception that pork is usually considered tender (Berg, 2000).

INTRAMUSCULAR FAT

Marbling is influenced by several intrinsic factors including gender, body weight, genetics, feeding, and carcass temperature (Kouba and Sellier, 2011). Juiciness scores in sensory panels have been shown to be positively correlated with intramuscular fat content (Mabry and Baas, 2001).

A study by Huff-Lonergan et al. (2002) investigated the correlations between meat quality traits. They found a strong correlation between marbling and firmness, suggesting that

"higher amounts of lipid may aid in improving the firmness of the product" when a product is chilled. In addition, they found that marbling was significantly correlated with tenderness measurements, drip loss, and percentage cook loss. When looking at traits correlated with objective color, they found that a lower L* value (darker color) tended to have lower percentage drip loss, was more tender, and had greater firmness scores (Huff-Lonergan et al., 2002). This study also reported a strong correlation of pH with sensory and Star Probe tenderness, while Dilger et al. (2010) found no significant correlation between shear force and pH.

While many studies have reported positive correlations between intramuscular fat and tenderness (Shackelford et al., 1994; Wood et al., 1996), it is likely that after cooking, the lipid component "acts as a lubricant in mastication of less tender meat" (Aberle et al., 2012). The flavor of fat can also cause a greater salivary response when chewing. It has also been suggested that the presence of fat might dilute the effects of the tougher myofibrils and cause an easier chew and dilution of connective tissue (Warriss, 2000).

While intramuscular fat content has been thought to affect eating experience of red meat, a recent study by Rincker et al. (2008), examining the relationship between IMF and sensory characteristics, failed to substantiate this theory. Sensory panels and shear force measurements were conducted and no relationship between palatability and extractable lipid content was found. Additionally, no difference in flavor intensity was reported across loin chops with differing levels of extractable lipid content. However, it was found that level of doneness greatly impacted palatability (Rincker et al., 2008).

Meat toughens when dry heat methods of cooking are utilized, because the rapid cooking does not allow for solubilization of collagen, and proteins will harden as the level of doneness increases (Aberle et al., 2012). There is also greater cooking loss when endpoint temperature

increases, which can affect perceived tenderness, juiciness, and overall palatability. Many psychological factors play into eating experience, and tenderness, juiciness, and flavor, all which affect overall palatability, are rarely evaluated separately. Most consumers look at the overall impression of meat to determine whether a cut is satisfactory (Aberle et al., 2012).

As marbling increases, flavor intensity increases. However, health conscious consumers tend to choose pork with less intramuscular fat (Rincker et al., 2008; Aberle et al., 2012). The consumer's desired level of marbling in the meat they purchase is related to their usual consumption pattern and may be impacted by geographic and ethnic influences (Savell, 1987). If a consumer is accustomed to consuming meat with high levels of marbling, this will influence their purchase decisions at the retail shelf (Savell, 1987; Cheng et al., 2015).

Visual appraisal has long been used by the beef industry to determine USDA quality grade codes that relate to the consumer potential differences in palatability and value (Savell, 1987). However, while the National Pork Producer's Council does have established standards for marbling, these standards are rarely used in the industry to differentiate value to the consumer. One of the reasons for this is that pork carcasses are not ribbed before fabrication (Cheng et al., 2015). Because visual appraisal does not account for human error and subjectivity, instrumental methods are being pushed for use in the industry in order to more accurately assess quality and improve production efficiency (Cheng et al., 2015).

It is important to understand the economic effects that quality grades have on the industry from the producer's point of view as well as the consumers. When premiums are available for higher quality products, there is incentive to genetically select animals that have the propensity to produce meat with greater percentages of intramuscular fat (Savell, 1987). The beef industry has focused on genetic selection for animals with high marbling scores while keeping excess

trimmable fat low and has raised the quality of beef raised and marketed in the United States (Cheng et al., 2015). This has improved the beef eating experience for consumers (Cheng et al., 2015).

Pork export markets, such as Japan, pay premiums for highly marbled pork with darker colored lean, leading processors to segregate product into quality-based groups. Differentiated lines of pigs are used based on the quality targets the industry needs in order to meet consumer demand. While it would be very difficult to measure pork quality using pH and colorimeter measurements during processing, subjective scoring of color, firmness, and marbling are used (Arkfeld et al., 2015).

Until quality grade standards are developed and implemented in the U.S. pork industry, contract growers are utilizing niche markets to enhance the value of their animals that produce more intramuscular fat in the lean cuts, such as Berkshire Gold.

ULTRASOUND TECHNOLOGY

Numerous researchers have taken advantage of the use of ultrasound technology to predict carcass composition and value for both swine and cattle (Newcom et al., 2002; Schinkel et al., 2010). Many improvements have been made in the livestock industry because of the increasing accuracy of this technology in measuring composition and meat quality. Genetic improvement programs have taken advantage of this convenient, cost effective research tool (McLaren et al., 1988; Cisneros et al., 1996; Jung et al., 2015). Alternatives, such as sib-testing and progeny programs come at a great cost to the producer in terms of both time and money (Newcom et al., 2002).

The accuracy of real-time ultrasound technology has been reported by numerous studies for predicting intramuscular fat percentage, longissimus dorsi depth and area, and 10th and last

rib backfat thickness (McLaren et al., 1988; Cisneros et al., 1996; Schwab et al., 2010; Jung et al., 2015). With real-time ultrasound, estimates of composition are based on the speed at which sound waves travel through tissues of differing density. Thus, as the sound waves move through the interfaces of tissues, a portion of the waves are reflected back to the source and the distance traveled can be calculated. Additionally, through computer analysis of the image's diffraction patterns, the amount of intramuscular fat can be accurately predicted (Newcom et al., 2002).

Jung et al. (2015) reported a strong correlation of chemical intramuscular fat and ultrasound intramuscular fat of 0.75 and 0.76, implying that real-time ultrasound can be used to measure intramuscular fat percentages in live swine. Another study looking at prediction of intramuscular fat in live swine reported a moderate correlation (Newcom et al., 2002). On an ultrasound repeatability study involving feedlot cattle, Hassen et al. (1999) reported overall repeatability of ultrasound-predicted percentage of intramuscular fat was .63 ± .03. A study by Lo et al. (1992) reported a high correlation between real-time ultrasonic measurements of backfat and carcass backfat measurements (0.71) along with a high correlation of ultrasonic loin eye area and the corresponding carcass measurement (0.75).

The use of ultrasound technology in the meats industry is expected to become more prevalent as producers are able to make better decisions about the genetic merit for carcass traits of their breeding stock.

THE IMPACT OF INCREASING SLAUGHTER WEIGHTS ON CARCASS QUALITY AND YIELD

The increase of slaughter weights has been a trend in the swine industry for over 20 years (Wiseman et al., 2007). Potential advantages in heavier weight carcasses could greatly impact the industry, as more pork is put in the market. Productivity per sow increases as overhead costs for

the producers are reduced and processors have the advantage of higher carcass yields as the meat to bone ratio increases (Moon et al., 2003; Correa et al., 2009; Magowan and McCann, 2009). Pigs marketed at higher weights have a "greater throughput of salable pork per unit of fixed investment" (Wiseman et al., 2007).

While there has been a steady trend with increasing slaughter weight, unexpected events in the swine industry have also caused this to be seen as an economically important area of research. The supply impact of the porcine epidemic diarrhea virus (PEDv) is uncertain since produces increased the weights of their hogs taken to market, in order to make up for loss of the number of hogs deceased (Schulz and Tonsor, 2015). From 2012-2014 the swine industry in the US was impacted by this virus that caused a reduction in pigs marketed per litter. In order to account for the loss in pig numbers, producers found it profitable to feed pigs to heavier weights, and packers accepted them without discounts (Schulz and Tonsor, 2015). An increase in slaughter weight has led to a need for more research and evaluation of carcass data to determine the economical impact of producing heavier hogs and the quality and cutability factors associated with it.

Changes in carcass composition and quality have been at the forefront of research pertaining to an increase in slaughter weight. Currently, the average slaughter weight for pigs in the United States is 284 lbs as of January 2017 and is expected to increase in the next few years (United States Department of Agriculture, 2017). While increasing slaughter weight can be a step towards increasing profitability, it is important for the industry to see what effects this move has on carcass merit.

As slaughter weight increases, the amount of excess trimmable fat increases. Subcutaneous fat deposition increases at a greater rate than intramuscular fat (Kouba and Sellier,

2011). Usually an increase in live weight comes with an increase in age at slaughter, which could affect meat quality attributes such as tenderness, as collagen becomes less soluble (Moon et al., 2003).

Latorre et al. (2004) studied the effects of slaughter weight (116, 124, and 133 kg) on carcass traits, growth performance, and meat quality. When looking at carcass cutability, a 10 kg increase in slaughter weight resulted in a linear increase in carcass length and an increase in ham circumference by 2.0 cm. The difference in slaughter weight from 116 to 133 kg resulted in a linear increase in back fat depth, fat over the gluteus medius, and dressing percentage. Trimmed ham and shoulder weights increased with slaughter weight; however, the primal yield percent for the ham and shoulder were not affected by slaughter weight (Latorre et al., 2004).

In terms of meat quality, they found that initial pH of the carcasses slaughtered at 133 kg was higher than the other two weight endpoints, but slaughter weight had no effect on 24-h pH . This study also found that slaughter weight had no effect on Warner-Bratzler shear force values or cooking loss percentage. Objective color measurements showed that with increasing slaughter weights, lightness (L*) decreased and redness (a*) increased significantly. (Latorre et al., 2004).

While there seems to be benefits to meat quality by increasing slaughter weights, this study also found that there was a decrease in live pig performance as slaughter weights increased. Pigs slaughtered at 116 kg had higher average daily gain, and gain:feed decreased linearly with increase of slaughter weight. Results of this study indicate that live pig performance and carcass leanness decreased with increasing slaughter weight with no improvements in quality attributes (Latorre et al., 2004). While this study did not measure intramuscular fat percentage, several studies have looked at this and have found little or no effects of intramuscular fat percentage with increasing slaughter weight (Martin et al., 1980, 1981; Garcia-Macias et al.,

1996). Cisneros et al. (1996) reported that subjective firmness and tenderness scores, moisture content, and and 24 hour pH all decreased significantly as slaughter weights increased.

While an increase in primal weights is expected with an increase in slaughter weight, percentage yields of these cuts have been found to decrease because of the added carcass fat (Cisneros et al., 1996). However, some studies have reported little change in percentage of primal cuts with slaughter weight (Martin et al., 1981).

Moon et al. (2003) reported higher protein and dry matter content for 115 and 125 kg slaughter weight compared to 95 and 105 kg. Like Latorre et al. (2004), they also reported increased subcutaneous fat as slaughter weight increased, no difference in shear force values among the different slaughter weights, a decrease in L* values as slaughter weight increased, and a significant decrease in cooking loss as slaughter weight increased in this study (Moon et al., 2003).

HIGH LEAN GROWTH VS. CONTEMPORARY SIRE LINES

Carcass composition and quality not only vary at different slaughter weights, but they also vary between genetic lines (Wiseman et al., 2007). Breed and genetic lines within a breed can greatly influence carcass traits and pork quality (Lee et al., 2012). Breeding programs have improved both carcass quality and feed efficiency (Moon et al., 2003). In order for companies to decide which genetic line would be best to produce, different populations with the same conditions must be tested at the same time (Mabry and Baas, 2001).

Many studies have been done looking at the differences between the Duroc and Pietran sire lines, which are utilized worldwide and vary in cutability and quality attributes (Edwards et al., 2003; Edwards et al., 2006). Meat from the Duroc line has been known to provide an excellent eating quality for consumers because of the high intramuscular fat content associated

with it (Warriss, 2000; Rincker et al., 2008), while carcasses from the Pietran line are leaner with an average quality (Edwards et al., 2006). Studying the effects of slaughter weight on both high-lean growth lines as well as quality based lines is important for understanding the economic benefits of raising certain sire lines (Correa et al., 2006).

A study by Lonergan et al. (2001) looking to "characterize the extent of the impact of selection for lean growth efficiency on fresh pork quality" evaluated carcass composition and quality in a line of Duroc pigs over five generations and compared them with a control line. The generations selected for lean growth had improved carcass lean, larger loin eye areas, and less overall fat on the carcass, but the quality in this line was reduced. There was a decrease in water holding capacity as measured by drip loss in the longissimus dorsi and semitendinosus and an increase in Warner-Bratzler shear force values (Lonergan, 2001). In addition, post mortem pH values were significantly lower in the line selected for high lean growth in the longissimus (at 15, 30, and 45 min postmortem) and the semitendinosus (at 15 min and 24 h postmortem), indicating an altered response in the muscle-to-meat conversion process, which has been known to largely influence pork quality (Lonergan, 2001; Scheffler et al., 2013).

In a study evaluating Duroc and Pietran-sired pigs for meat quality and carcass measures, Edwards et al. (2003) found that Pietran progeny had a higher percentage of lean at slaughter as well as a higher dressing percentage when animals were slaughtered at a common age (26 weeks). The progeny from the Duroc line were shown to have heavier slaughter weights, longer carcasses, lower dressing percentage, and more backfat at the first rib, tenth rib and last lumbar vertebrae when compared to the Pietran progeny. Duroc also had a greater percentage of belly weight but lower percentage of ham and loin weights. Boston butt and picnic shoulder

percentages were similar. Pietran progeny also had a higher percentage of total weight from the five primal cuts (Edwards et al., 2003).

When quality attributes were measured, the progeny of the Duroc line had "more favorable" color, marbling, and firmness scores, a higher pH, lower drip loss percentage, and a higher Minolta a* value, with no significant difference in L* and b* objective color scores. There was also no significant difference found in Warner-Bratzler shear force values (Edwards et al., 2003).

While this study looked at both lines at the same age, another study was conducted slaughtering at targeted weight endpoints. Wiseman et al. (2007) evaluated body measurements, composition, and quality among two different lines, one considered high lean and the other considered low lean. They harvested both barrows and gilts in 25 kg increments from 20 to 125 kg live weight. This study found that the high lean line had larger loin eye areas, less backfat, and an increase in FFL tissue as body weight increased. The low lean line had an increase in backfat depth along with bone mineralization, causing a lower percent FFL as body weight increased. No significant differences between the two lines for L* and a* values were reported. However, as body weight increased for both lines, b* increased linearly (Wiseman et al., 2007).

When evaluating body measurements, body length was longer in the live animal for the high lean line at each weight end point and had a greater height from 20 kg to 100 kg. Widths were similar at the heavier weights (Wiseman et al., 2007).

Selecting for carcasses with less backfat has led to a decrease in intramuscular fat percentage (Warriss et al., 1990; Warriss, 2000; Newcom et al., 2005). Subcutaneous backfat depth and intramuscular fat content have been found to have a moderately positive correlation (Newcom et al., 2005).

Carcasses are now receiving discounts if they are exceptionally lean (Mabry and Baas, 2001). When carcasses do not possess a minimum amount of intramuscular fat, cold shortening in the cooler can occur which greatly affects pork quality and can affect pH at slaughter (Scheffler and Gerrard, 2007). A decrease in tenderness can also occur if muscle temperature drops very low before reaching final pH (Scheffler and Gerrard, 2007). In addition the reduction in belly thickness causes a loss to the producer, as ultra-lean bellies do not produce adequate quality bacon (Mabry and Baas, 2001).

SLAUGHTER WEIGHT AND THE BACON MARKET

Traditionally, lean content and pork market value was determined for the entire carcass, however, pork packers are now assessing primal values. Pork carcasses vary in quality and lean composition among their different primal cuts, and overall carcass composition is no longer effective in determining the true value of the carcass (Tholen et al., 2003).

Producing leaner carcasses has had the greatest negative impact in the belly, the most valuable primal cut of the pork carcass (Tholen et al., 2003; Correa et al., 2008). Exceptionally lean carcasses often receive discounts because of the loss in value of the belly (Mabry and Baas, 2001). One of the advantages of increasing slaughter weights would be the production of thicker bellies, yielding higher percentages of bacon. Currently, the U.S. retail average price for bacon is $5.03/ lb and is expected to climb (United States Department of Agriculture, 2017). Fast food restaurants as well as slow food have multiplied the use of bacon on their menus. The belly makes up about 16% of a pork carcass and thus is a significant economic portion of the carcass value (Soladoye et al., 2015). Breed, sex, slaughter weight, and age at slaughter all affect pork belly quality, but there are different ideas between consumers and producers of what determines quality in pork bellies (Soladoye et al., 2015).

Belly firmness and thickness greatly impact processing yields, as thicker bellies have been found to have the highest processing yields (Person et al., 2005; Soladoye et al., 2015). Firmer, heavier bellies have a higher lipid deposition which can increase belly curing yields (Cisneros et al., 1996; Correa et al., 2008).

Most manufacturers have standards for bacon based on lean to fat ratio and uniformity that classify packages into either grades 1 or 2, with grade 1 considered the best (Soladoye et al., 2015). Bellies that are too thin minimize bacon revenue because low processing yields cause much of the bacon produced to be packaged as "#2 slices" or end up in the ends and pieces market. While much of this is of great concern to processors, consumers are more focused on visual lean to fat ratio of packages as well as palatability. When comparing bacon from thin, average, and thick bellies, consumers have been found to discriminate against bacon produced from thick bellies when looking at the overall leanness in slices (Person et al., 2005).

In addition, fatty acid composition varies with belly thickness. Thin bellies have a higher percentage of unsaturated fat while thicker bellies have a higher percentage of saturated fat. This can affect flavor profile and also shelf life since unsaturated fatty acids are more prone to rancidity (Person et al., 2005; Correa et al., 2008). Growth rate of the animal affects fat accretion and therefore belly fat content because animals with faster growth rates will have fatter carcasses when compared with slower growing pigs (Correa et al., 2008).

GENDER

Numerous studies have shown differences in carcass merit and growth rate among gilts and barrows. Barrows generally mature and fatten more quickly than gilts (Aberle et al., 2012). In a study with crossbred pigs, Latorre et al. (2004) found that barrows have lower dressing percentages, fatter carcasses, and lighter trimmed hams and shoulders than gilts. In addition,

barrows also had a lower semimembranosus pH (both for initial and ultimate). When looking at composition, protein content of the longissiumus for barrows was less than the gilts, but there were no significant differences between moisture and lipid content in the two genders. Cook loss percentages as well as Warner Bratzler shear force values were less for barrows than gilts (Latorre et al., 2004).

Wiseman et al. (2007) reported larger loin eye areas and less backfat thickness for gilts when compared to barrows which is similar to the findings of Cisneros et al. (1996). They also found no significant differences between barrows and gilts when L*, a*, and b* values were analyzed (Wiseman et al., 2007). This study also found that protein content was higher in gilts than barrows. Cisneros et al. (1996) reported that subjective firmness, marbling, and color scores were higher for barrows than for gilts.

SUMMARY

Improvements have been made in the swine industry in the last several decades in terms of reproduction, growth rate, leanness, and meat quality. The desire for enhanced product uniformity has been coupled with the need for more differentiation in retail products (i.e., quality vs yield). Increased information about sire lines will benefit both the commodity and value-added markets. While significant strides have been made in providing a safe, wholesome, and desirable end product for consumers to purchase, there is still much research needed regarding improvements in genetic lines, growth efficiency, and weight endpoints, all which must take into account market signals being portrayed by consumers.

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CHAPTER 3

THE EFFECTS OF SIRE LINE, SLAUGHTER WEIGHT, AND GENDER ON PORK QUALITY AND YIELD CHARACTERISTICS[1]

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ABSTRACT

The U.S. swine industry has placed a premium on lean growth in order to meet growing consumer demand for lean, affordable pork products. At the same time, growing global demand for pork as well as increased penetration of pork into the foodservice market has led to emphasis on genetic lines that emphasize high quality. As the U.S. pork industry continues to grow it is important to understand how slaughter weight impacts carcass value in lines of pigs selected for lean growth and those selected for meat quality. In this study, lean yield line (LYL) and meat quality line (MQL) boars were mated to PIC C-42 females to determine the effects of sire line, gender, and slaughter endpoint on carcass quality and yield attributes. When pigs reached 23 kg, three pigs within a litter and gender category were randomly assigned to slaughter weights of 113, 136, and 159 kg. Upon reaching their assigned weight, pigs were slaughtered under inspection. A total of 108 offspring from 18 litters, 9 litters per line, were evaluated. After slaughter, loin pH was measured and carcasses were chilled at -2°C. After 24 h, loin pHu, carcass muscle score (CMS), carcass length, tenth rib back fat (TRBF), last rib back fat (LRBF), loin eye area (LEA), NPPC color and marbling scores, and Hunter L* a* b* were measured in the longissimus muscle. Carcasses were fabricated, and primal and subprimal weights were recorded. After fabrication, samples were removed from the longissimus for proximate anterior to the 11th rib, drip loss, and Warner Bratzler and slice shear force determination. Skinless belly dimensions (length, width, and depth) and firmness were recorded. Data were analyzed using GLM procedures with the main effects of sire line, gender, and slaughter endpoint and LSMEANS were separated using LSD. The LYL had higher ($P < 0.01$) CMS than the MQL, but the MQL had longer ($P = 0.01$) carcasses than the LYL. The MQL had more ($P < 0.01$) TRBF and LRBF than the LYL. LEA and LRBF increased as weight increased ($P<0.01$), along with an

increase ($P < 0.01$) in TRBF from 113 to 136 kg. The LYL gilts had darker ($P < 0.05$) loin color scores than the MQL gilts. As expected, the MQL had greater ($P < 0.01$) marbling scores than the LYL, with no differences ($P = 0.29$) noted across slaughter endpoints. Hot carcass weight was heavier ($P < 0.01$) for the MQL vs LYL. Primal weights and boneless cut yield increased ($P < 0.01$) as slaughter weight increased. The LYL exhibited greater ($P \leq 0.03$) cut yields when expressed as a percentage of side weight than the MQL for the lean cuts; however, the MQL exhibited greater ($P \leq 0.05$) cut yields than the LYL for the fatter cuts. The LYL and gilts had a greater ($P < 0.01$) percent fat free lean than the MQL and barrows, respectively. Lipid content was greater ($P < 0.01$) in the longissimus from the MQL vs LYL and barrows vs gilts. Slice shear values were lower ($P = 0.01$) for the LYL than the MQL, but Warner Bratzler shear did not differ. Consistent advantages in lean yield existed in the LYL compared to the MQL. Increasing slaughter weight increased the pounds of boneless cuts; however, due to fat accumulation, increasing slaughter weight negatively impacted lean yield for both lines. No quality differences were found as carcass weight increased; however the MQL carcasses had greater marbling scores than the LYL. Advantages in meat quality were not as consistent across sire lines as were advantages in yield.

INTRODUCTION

The swine industry has placed a premium on lean growth in order to meet growing demand for lean, affordable pork products. Increased pork supply has come in large part from increased market weights (Cisneros et al., 1996; Lonergan et al., 2001). Unexpected events in the swine industry have caused this to be seen as an economically important area of research, as hog numbers have fluctuated in response to feed prices and health issues like the porcine epidemic diarrhea virus. The supply impact of the porcine epidemic diarrhea virus was uncertain mainly

due to an increase in hog weights, and packers accepted heavier hogs without discounts (Schulz and Tonsor, 2015). At the same time, growing global demand for pork as well as increased penetration of pork into the foodservice trade has led to emphasis on genetic lines of pigs that produce high quality pork products. Improvements have been made in the swine industry in the last several decades in terms of reproduction, growth rate, leanness, and meat quality (Moon et al., 2003; Miar et al., 2014). The desire for enhanced product uniformity has been coupled with the need for more differentiation in retail products (i.e., quality vs yield) (Merks, 2011). Therefore, retail is placing emphasis on two different pork markets: commodity vs. value-added (Mabry and Baas, 2001). Producing the highest quantity of muscle tissue has been a goal for the industry for a long time, while merit buying programs have increased the desire for producers to raise animals for lean yield as well as meat quality (Lonergan et al., 2001). Different sire lines have varying genetic propensities for both lean yield and meat quality (McLaren et al., 1987; Ellis et al., 1996; Edwards et al., 2003). Differences in both percentage of lean cuts as well as meat quality attributes have been recorded between sire lines as well as difference in carcass cutability (Cisneros et al., 1996; Edwards et al., 2003; Wiseman et al., 2007). As the pork industry continues to grow, it is important to understand how market weight impacts carcass value in lines of pigs selected for lean growth, as well as those selected primarily for quality. Thus, this study is designed to determine the effect of slaughter weight on carcass composition and meat quality attributes of a lean yield sire line and a meat quality sire line slaughtered at increasing weight endpoints.

MATERIALS AND METHODS

Two composite sire lines, a lean yield line (LYL) and a meat quality line (MQL), were mated to Pig Improvement Company (PIC) sows (LYL x PIC C42 and MQL x PIC C42; n = 9

litters per line) at the University of Georgia Swine Unit during 2016. From each litter, 3 barrows and 3 gilts (closest in weight to the average of the litter) were selected for the study and were randomly assigned to one of three different slaughter weight endpoints (113, 136, and 159 pounds) once the average of the litter reached 23 kg. The pigs were then housed at the University of Georgia Swine Unit and managed under typical industry practices until slaughter.

Pigs were weighed weekly as they approached their designated slaughter endpoint and pulled for slaughter when their weights were within 4.5 kg of their slaughter weight one week prior (i.e., 109, 132, 154 kg).

All pigs were provided diets on ad libitum basis that met or exceeded their nutritional requirements during each stage of production.

Carcass Temperature and pH

As the pigs reached their assigned slaughter weights, they were transported to the University of Georgia Meat Science and Technology Center the day prior and held overnight without feed but free access to water. The next morning they were slaughtered under inspection. Slaughter weights and hot carcass weights were recorded. Immediately prior to lactic acid spray and chilling of the carcasses, muscle pH (< 1 h postmortem; RS 232 Meter; Cole Parmer, Eutech Instruments; Singapore) was recorded from the longissimus muscle between the 7^{th} and 8^{th} ribs and in the semimembranosus muscle of the ham. All measurements were taken from the right side of the carcasses.

Temperature recorders, iButton Technology (1-Wire Thermochron DS1921G#F50; Maxim Intergrated Products, Inc., San Jose, CA) were then placed in the same general regions of the loin and ham 5 minutes post washing and prior to lactic acid spray. Muscle temperature was

recorded every minute until carcass data was collected the following day (approx. 24 h). Carcasses were then chilled at -1°C overnight.

Carcass Measurements

About 22 h postmortem, carcass length from the first rib to the aitch bone as well as USDA carcass muscle score were recorded. Carcasses were then ribbed between the tenth and eleventh ribs, and tenth rib backfat (¾ of length) and last rib fat thickness (midline) were measured. iButton temperature recorders were removed from both the loin and semimembranosus. Loin eye area was traced on transparency paper and later analyzed using ImageJ 1.51d software (Wayne Rasband, National Institutes of Health; Bethesda, MD).

Loin Quality Measurements

At the tenth rib loin eye, subjective quality scores and objective measures of the loin were taken after the loin eye was given a minimum of 15 min to bloom. A subjective color score was recorded using the NPPC Color Score (0.5 point) as well as an NPPC Marbling Score (0.5 point). In addition a lean firmness score was taken (0.5 point) on a 1-5 scale (1 = very soft to 5 = very firm).

A Hunter colorimeter (Hunter MiniScan XE Plus-45/0-L, Hunter Associates Laboratory; Reston, WV) was placed on the loin eye (after a calibration of pure white and black tiles) to measure L*, a*, and b* using illuminate D65 after a 15 min bloom time. Next, ultimate pH was measured at the tenth rib in the longissimus muscle as well as the semimembranosus muscle of the ham.

Carcass Fabrication

Carcasses were fabricated according to NAMA (2014) specifications with slight modifications. Prior to fabrication, side weights were recorded for all right sides of the carcasses.

Primal weights were recorded during fabrication of the ham (401A) and skinless ham (401C) and subprimals: outside ham muscle (402E), inside ham muscle (402F), and knuckle (402H); the picnic shoulder (405) and boneless picnic shoulder (405A); the Boston shoulder (406) and boneless Boston shoulder (407), trimmed to 6 mm fat; belly (408), skinless belly (409), and spareribs (416); the bone-in loin (410) and boneless loin, trimmed to 0 mm fat, (413C) and subprimals: tenderloin (415) and boneless sirloin, trimmed to 6 mm fat (413D).

Following separation from the loin and belly, hams were given 15 min to bloom, and Hunter colorimeter measurements were taken as well as pH, both at the gluteus medius and the gluteus profundus muscles. Hams were then fabricated and subprimal weights recorded.

Belly Dimensions and Firmness

Belly width at the half mark and belly length from dorsal to caudal end were measured in centimeters. Belly thickness (cm) was measured in the center of the belly starting at the cranial end, and then at the ¼, ½, and ¾ length and the caudal end.

Belly firmness was measured using the flop method according to the procedures of Thiel-Cooper et al. (2001), and distance from end to end of the dorsal and ventral sides were measured simultaneously after the belly was placed over the bar and allowed to flop for 3 seconds. Distance in centimeters was recorded from inside of the fat side to inside of the fat side.

Sample Removal

Following fabrication, a portion of the loin was removed from the 11th to last rib region and used for the following quality and composition determinations: proximate analyses (protein, moisture, fat sampled anterior to the 11th rib), slice shear force (14 d aged), Warner-Bratzler shear force (14 d aged), and 24 h drip loss.

Slice and Warner-Bratzler shear force and proximate analysis chops were vacuum packaged, blast frozen, and stored at -40°C until analyzed.

Drip Loss

Drip loss was determined using the procedures outlined by Honikel (1997). After fabrication, 50 g longissimus dorsi samples were weighed, suspended by a fishing hook, and stored at 2°C for 24 h in a sealed bag, without touching the bag. After 24 hours, samples were taken down, fish hooks removed, and samples were blotted on each side before a 24 h weight was recorded to calculate drip loss percentage.

iButton Temperature Recorders

Temperature recordings were uploaded after each use. Hour 0 was estimated at the time a minute before carcasses entered the blast freezer, and hour 24 was used for the time right before carcasses were taken out of the blast freezer and moved to the cooler.

Proximate Analyses

For proximate composition of the Longissimus dorsi, chops were trimmed of all external fat and frozen in liquid nitrogen. Immediately after, samples were powder homogenized in a Waring commercial blender (Model 34BL97, Dynamics Corporation of America, New Hartford, CT).

For moisture (AOAC, 2006) and lipid determination (Komarek et al., 2004), samples were weighed in duplicate and placed into a drying oven at 100°C overnight. Weights were collected to determine moisture loss using the equation: Moisture (%)= 100 x ((filter bag weight + sample weight) – weight after drying) / sample weight. Samples were placed into an Ankom Fat Extractor XT15 (Ankom Technology, Macedon, NY) for 4 h. Following extraction, samples were placed in a 100°C oven for 15 minutes, allowed to cool in a desiccator and weighed to

determine lipid content using the equation: Fat (%)= ((pre-dried sample weight - dried weight after extraction) x 100)/ wet sample weight.

For protein determination (AOAC, 2006), samples were weighed out to 0.2000- 0.2099 g in triplicates and placed into a LECO FP-628 Protein Analyzer (LECO Corp, St. Joseph, MI) to determine Nitrogen content. Crude protein was calculated using the following equation: CP = %N x 6.25.

Shear Force Evaluation

Shear force chops were individually packaged after fabrication and aged for 14 d at 2°C. They were then frozen until slice shear and Warner-Bratzler force determination.

Slice shear force chops were removed from their individual packages, and a frozen weight on each chop was recorded. Chops were allowed to thaw overnight (4°C), and a thawed weight was recorded the following morning. Copper-constantan thermocouples attached to a potentiometer were placed approximately in the geometric center of each chop. Chops were cooked using George Foreman grills and cooked to an internal temperature of 65°C. Cook time was recorded. Immediately after chops were taken off the grill, a cooked weight was recorded to determine cook loss. Two pieces, 2.5 cm thick and 5 cm long, from the lateral end were cut using a 45° slice box and a knife consisting of two parallel blades to allow for perpendicular fiber orientation during shearing. Samples were then analyzed using an Instron Universal Testing Machine (5 N load cell; Instron Corp. Worldwide Headquarters; Dual Column Model 3365; Norwood, MA) using a 1.02 mm thick blade travelling 500 mm/min.

Warner Bratzler samples were removed from the freezer and a frozen weight was recorded. Chops were thawed overnight and a thawed weight was recorded, prior to cooking. Chops were cooked to an internal temperature of 71°C and cook time and cooked weight were

recorded. Chops were then placed back into cooler at 2°C overnight, and Warner Bratzler shear force was performed the following day. Six 1.27-cm diameter core samples were analyzed with an Instron Universal Testing Machine using a 1.02 mm thick blade travelling 500 mm/min perpendicular through the muscle fibers.

Statistical Analysis

Data were analyzed using GLM procedures (SAS 9.4, SAS Inst., Inc., Cary, NC) with the main effects of sire line, gender, and slaughter endpoint. Main effects and their interactions were tested. Animal was the experimental unit used in this analysis. Least square means were separated using least significant difference procedures. Results were deemed significant at $P \leq 0.05$. For Warner-Bratzler and slice shear force, degree of doneness was used as a covariate.

RESULTS AND DISCUSSION

Temperature

The iButton temperature data for the semimembranosus and the longissimus measurements are shown in Table 3.1. For the ham, there were no differences ($P>0.15$) in temperature decline between the sire lines or genders. Ham temperature was significantly warmer at 12 h in carcasses from the heaviest (159 kg) versus the lightest (113 kg) slaughter weights, however, slaughter weight did not impact ham temperature at any other measurement time.

Loin temperatures did not differ between sire lines except that the MQL carcasses were warmer ($P=0.05$) than the LYL at 1 h postmortem. Loin temperatures from the 113 kg group were colder ($P=0.01$) at 0, 1, and 3 h when compared to the 136 and 159 kg groups. Temperature increased ($P<0.01$) as endpoint weight increased at 8 and 12 h, indicating a slower rate of temperature decline for the heavier carcasses. Barrows had warmer ($P<0.04$) loin

temperatures than gilts at 0, 1, 8, and 12 h and tended (P=0.09) to have warmer loin temperatures at 3 and 24 h postmortem. All temperatures were below 0°C for both the loin and ham after 24 h of chilling. The differences in loin temperatures are consistent with the compositional differences noted in Table 3.2, particularly that MQL and barrow carcasses had more backfat than those from LYL and gilts. Additionally, backfat increased (P<0.05) incrementally, similar to loin temperature, as slaughter weight increased.

Carcass, Loin, and Ham Measurements

As shown in Table 3.2, slaughter weight did not differ (P>0.30) across sire line or gender; however, carcass weight was heavier (P<0.01) in the MQL versus the LYL carcasses. Dressing percentage means were not affected (P>0.09) by sire line, slaughter weight or gender. In accordance with the design of the experiment, slaughter and carcass weights were significantly different across the end point groups.

As expected, the MQL carcasses had greater (P<0.01) 10^{th} rib back fat and last rib back fat than the LYL carcasses. 10^{th} rib backfat increased significantly from 113 to 136 kg. As slaughter weight increased, last rib backfat increased incrementally (P<0.01). While no interactions were seen in this study between sire line and slaughter end point for back fat, Wiseman et al. (2007) reported a significant impact of slaughter weight on back fat thickness, with the high-lean genetic line having a significantly less back fat at each weight endpoint.

The LYL carcasses tended to have larger (P=0.08) loin eye areas and higher (P<0.01) carcass muscle scores than their MQL counterparts. Loin eye area increased incrementally (P<0.01) as slaughter end point weight increased. However, no differences (P=0.62) in carcass muscle scores were seen across slaughter weights. Wiseman et al. (2007) and Lonergan et al. (2001) found that high lean lines had larger loin eye areas and less back fat than low lean lines.

As is common for gender differences in pork, males had greater ($P<0.01$) 10^{th} rib backfat, lower ($P=0.02$) carcass muscle scores and smaller ($P=0.01$) loin eye areas than females. These gender effects are consistent with the findings of Wiseman et al. (2007) and Cisneros et al. (1996).

Carcass length was significantly impacted by sire line and endpoint, with the MQL exhibiting longer carcasses ($P=0.01$) than the LYL, and as slaughter weight increased, carcass length increased ($P<0.01$). A significant interaction (Table 3.14) was seen for carcass length between sire line, gender, and weight endpoint. Carcasses from the 159 kg males were longer in the MQL than 159 kg males from the LYL.

In agreement with the compositional differences found across the main effects, carcass fat free lean (FFL) percentage was higher ($P<0.01$) in the LYL vs MQL and gilts vs barrows. As slaughter weight increased FFL decreased due to higher levels of carcass fat; however, the difference between the 136 kg and 159 kg groups was not significant. Contrary to these findings, Wiseman et al. (2007) found that there was an increase in fat free lean tissue as body weight increased in the lean yield line they studied.

No significant differences were seen for initial pH (measured less than 1 h postmortem) or pHu in the loin among any of the main effects (Table 3.3). However, the LYL tended to have a higher ($P=0.06$) 1 h ham pH than the MQL.

No differences were seen in NPPC loin color scores across sire line. The 159 kg group had significantly higher loin color scores than the 113 kg group, with loin color scores for the 136 kg group being intermediate. The LYL females had higher ($P=0.02$) color scores than the MQL females (Table 3.11). The three way interaction (Table 3.14) for loin color ($P=0.04$)

showed LYL barrows had higher color scores at 159 kg than 113 and 136 kg, and LYL females at 113 kg were significantly darker than MQL females at the same endpoint.

Marbling scores were higher ($P<0.01$) for the MQL than the LYL, and males had greater ($P<0.01$) marbling scores than females. No differences ($P>0.07$) in lean firmness were seen across sire line and gender, but a trend ($P = 0.07$) was noted for slaughter weight endpoint with the lighter weight carcasses receiving lower firmness scores. For gender differences these results are similar to Cisneros et al. (1996) that found barrows had higher marbling scores than gilts, but contrary to this study they found that barrows also had darker color scores and higher firmness scores, while this study found no significant differences for those between the two genders.

Lightness (L*) and redness (a*) values in the loin were similar ($P>0.25$) across sire line, slaughter weight and gender and b* (yellowness) values were similar ($P>0.45$) between sire lines and weight endpoints (Table 3.3). However, b* measurements of the loin were higher ($P=0.01$) in barrows compared to gilts, meaning the gilts had bluer loin lean. No differences ($P>0.10$) in percent drip loss were found in this study.

While quality differences between the two sire lines chosen for this study were minimal, Lonergan et al. (2001) found a decrease in quality while comparing a high lean yield line with a control line, shown by lower pH values post mortem, a decrease in drip loss, and an increase in Warner-Bratzler shear force values. In addition, Edwards et al. (2003) found a higher pH and more favorable color, marbling, and firmness scores for a meat quality line vs a lean yield line, but no difference in Warner-Bratzler shear force values.

For ham quality, the pHu from the gluteus medius and gluteus profundus did not differ ($P>0.10$) across sire line, endpoint weight or gender. The MQL had lighter ($P=0.03$) L* gluteus medius and L* gluteus profundus values than the LYL (Table 3.4). Barrows had significantly

lighter L* gluteus profundus values than gilts. There was no effect of endpoint weight on ham pH and color measures, however, there was a significant interaction between sire line and weight endpoint for L* in the gluteus medius. The MQL at 159 kg were lighter ($P<0.05$) than all sire line endpoint combinations except for the MQL at 113 kg. The LYL at 159 kg were significantly darker than the MQL at 159 kg, suggesting that the high lean growth line had darker ham gluteus medius muscles once the 159 kg weight was reached.

There was also an interaction ($P=0.04$) between sire line and gender for a* in the gluteus profundus. The MQL males and females differed ($P<0.05$) from each other, with MQL males having a lower a* value, suggesting a redder tone in the gluteus profundus.

There was a three-way interaction for gluteus medius pH ($P=0.05$). The LYL gilts at 159 kg were less acidic than the LYL barrows, and LYL barrows at 113 kg were less acidic than LYL barrows at the 159 kg endpoint.

Weights

The MQL had heavier ($P=0.01$) bellies and skinless bellies than the LYL (Table 3.5). While whole ham weights did not differ ($P=0.44$) across sire lines, the inside ham and knuckle were heavier ($P=0.02$) for the LYL than the MQL. Boneless cut yield did not differ ($P=0.19$) among sire lines.

As expected, all primal and subprimal weights increased ($P<0.01$) as end point weight increased, except for the boneless sirloin which did not differ ($P=0.83$) among slaughter endpoints. Boneless cut yield increased significantly with an increase in slaughter weight as well.

Barrows had heavier ($P=0.03$) skinless bellies than gilts, but gilts had heavier ($P<0.01$) loins than barrows. Gilts had significantly heavier sirloin, ham, skinless ham, inside ham, and

outside ham weights than barrows. In addition, gilts had a greater ($P<0.01$) boneless cut yield than barrows in this study.

Table 3.6 shows primal and subprimal weights expressed as a percentage of side weight. In general, sire line differences in cut weights showed greater percentages of lean cuts for the high lean growth line and greater percentages of the fatter cuts for the quality-based line. The MQL had significantly greater percent boneless Boston shoulder and percent skinless belly than the LYL. The LYL had greater ($P=0.03$) percentage of loin, percent boneless loin, percent ham, percent skinless ham, percent inside ham, and percent knuckle. The LYL also had a greater ($P<0.01$) percent of boneless cuts than the MQL.

Percent Boston shoulder was greater ($P=0.02$) at 136 kg compared to 113 and 159 kg and the percentage of skinless belly was significantly lower at 113 kg than 136 and 159 kg. Percent skinless ham at 113 kg was lower ($P=0.01$) than 136 kg. Percentages of inside and outside ham at 113 kg were significantly higher than 136 and 159 kg. Percent of knuckle was greater ($P=0.03$) at 113 than 159 kg. This study had similar findings to Edwards et al. (2003) and Martin et al. (1980) who found that as slaughter weight increased, skinless belly percentages increased and skinless ham percentages decreased. However, Martin et al. (1980) found that loin percentages increased, while this study found that percentage loin decreased as slaughter weight increased from 113 kg to 136 kg.

Males had a greater ($P=0.01$) percentage of skinless belly weight than females, but females had a greater ($P=0.04$) percentage of tenderloin, skinless ham, inside ham, and outside ham than males.

The increase in back fat from 113 to 136 kg caused a decrease in percent yield (Table 3.6) as well as a decrease in percent fat free lean (Table 3.2), the LYL had a greater ($P<0.01$) percent fat free lean and percent of boneless cuts than MQL.

Belly Measurements

The MQL had thicker ($P=0.03$) bellies at the caudal end and tended ($P=0.09$) to have on average thicker bellies than the LYL. No differences ($P>0.40$) were seen between length, width, or firmness between sire lines.

Several belly measurements had significant effects in terms of end point weight. Length and width were different ($P<0.01$) among end points, with an incremental increase in both as end point weight increased. At the ¼ length mark, bellies from carcasses at 136 kg were thicker ($P<0.01$) than bellies from the 113 kg group. Belly depth taken at the ½ length site was higher ($P<0.01$) at 159 kg than the other two endpoints. The cranial end, the ¾ length, and the caudal end for bellies from the 113 group were significantly thinner than the other two endpoints. Average thickness increased ($P<0.01$) as weight increased.

Females had wider ($P=0.04$) bellies, but males had thicker ($P=0.02$) bellies at the half mark, the caudal end, and had a greater average thickness.

Proximate Composition

Moisture and protein content of the loin was not different ($P>0.10$) across the main effects investigated in this study (Table 3.8). This is contrary to the findings of Moon et al. (2003) that reported a greater protein and dry matter content for hogs of heavier slaughter weights compared to lighter slaughter weights. Lipid content was different for both sire line and sex. The MQL had a greater ($P<0.01$) lipid content compared to the LYL, and barrows had a greater ($P<0.01$) lipid content than gilts. This is consistent with the differences noted in marbling

scores between the sire line and genders (Table 3.3) Latorre et al. (2004) and Cisneros et al. (1996) found that barrows had lower loin protein content than gilts but lipid and moisture levels were unaffected.

Shear Force

Degree of doneness was used as a covariate for Warner Bratzler (WBSF; Table 3.9) and slice shear force (SSF; Table 3.10) analyses. None of the cooking parameters were affected ($P>0.15$) by sire line or gender; however, when comparing weight endpoints, chops from the 159 kg endpoint had less ($P=0.05$) thaw loss and required longer ($P=0.01$) cook times to reach 71°C internal temperature than the 136 kg endpoint. Longissimus tenderness, measured by WBSF, was not affected by sire line, endpoint weight or gender. Edwards et al. (2003) also found no differences in Warner-Bratzler shear force values between the two sire lines they study. The targeted value for tenderness by the NPPC is less than 3.2 kg for Warner-Bratzler values (Berg, 2000). However, there is lack of research looking at threshold tenderness for pork, primarily due to the perception that pork is usually considered tender (Berg, 2000). All LSmeans in this study were below the 3.2 kg threshold.

Slice shear force values (Table 3.10) were lower ($P=0.01$) in the LYL compared to the MQL loin chops. This suggests that the quality-based line was less tender than the lean yield line. Slice shear force degree of doneness showed a higher ($P=0.05$) degree of doneness for the 159 kg endpoint than the 113 or 136 kg endpoint. Additionally, cook time for the 159 kg endpoint was significantly longer ($P<0.01$) than cook times for either the 113 or 136 kg endpoint. This could be due to differences in size of the loin chops.

IMPLICATIONS

Consistent advantages in lean yield existed in the LYL compared to the MQL. Increasing slaughter weight increased the pounds of boneless cuts; however, due to fat accumulation, increasing slaughter weight negatively impacted lean yield for both lines used in this study. While there was not an increase in meat quality with increasing weight, there was not a reduction either. Advantages in meat quality were not as consistent across sire lines as were advantages in yield. These results suggest that animals with the genetic propensity to produce high quality pork or a high lean yield need further research to determine whether it would be advantageous to continue the gradual increase in market weights. This study revealed that differences in lean yield were large between the two sire lines investigated. While there are advantages in value (total $) from the extra pounds produced from heavier carcasses, the decrease in lean yield for both lines as slaughter weight increased should be kept in mind for producers desiring premiums for high lean carcasses. Quality advantages were minimal between sire lines. Depending on the quality attribute desired (marbling, tenderness, color, etc), the benefits of using lean yield genetics may outweigh the benefits of using the meat quality line as the demand for pork supply continues to increase. More research targeting quality attributes of pork and consumer satisfaction should be done to determine which quality traits should be the focus of the selection programs in the U.S. swine industry. Increases in cut weights, such as the skinless belly, could improve profit margins if the MQL lines are grown to heavier weights. This could be particularly beneficial to the bacon market. Significant yield and quality differences were seen in barrows vs gilts, suggesting that perhaps further research might be needed in seeing how segregated feeding during production could increase profits by targeting them at two different markets.

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Table 3.1 Effect of sire line (S), weight endpoint (W), and gender (G) on carcass temperature decline for the ham and loin regions

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
Ham														
0 h	37.9	37.7	0.64	37.8	37.6	38.0	0.61	37.9	37.8	0.86	0.63	0.33	0.59	0.78
1 h	27.3	26.9	0.56	27.6	26.6	27.0	0.47	26.6	27.6	0.15	0.24	0.77	0.90	0.56
3 h	18.0	18.0	0.99	18.2	17.6	18.3	0.52	17.8	18.3	0.37	0.97	0.51	0.33	0.22
8 h	7.5	7.4	0.75	7.2	7.1	8.1	0.07	7.5	7.4	0.90	0.90	0.68	0.29	0.22
12 h	3.7	3.5	0.36	3.1[a]	3.6[ab]	4.1[b]	0.01	3.7	3.5	0.42	0.89	0.25	0.41	0.23
24 h	-0.54	-0.48	0.60	-0.6	-0.59	-0.34	0.10	-0.52	-0.50	0.83	0.29	0.47	0.31	0.17
Loin														
0 h	37.9	37.9	0.94	37.2[a]	38.2[b]	38.3[b]	0.01	38.3	37.5	0.01	0.93	0.24	0.85	0.78
1 h	32.9	33.8	0.05	31.6[a]	34.2[b]	34.2[b]	<0.01	33.8	32.9	0.03	0.07	0.06	0.34	0.59
3 h	21.5	22.1	0.21	19.1[a]	22.8[b]	23.5[b]	<0.01	22.2	21.4	0.09	0.42	0.14	0.10	0.79
8 h	7.9	8.6	0.08	5.9[a]	8.7[b]	10.0[c]	<0.01	8.8	7.7	0.01	0.55	0.12	0.15	0.69
12 h	2.9	3.3	0.13	1.5[a]	3.4[b]	4.3[c]	<0.01	3.5	2.7	<0.01	0.35	0.13	0.11	0.75
24 h	-0.54	-0.48	0.58	-0.59[a]	-0.59[a]	-0.34[b]	<0.01	-0.52	-0.5	0.09	0.09	0.22	0.18	0.83

[a, b, c] Means differ (P<.05)

Table 3.2 Effect of sire line (S), weight endpoint (W), and gender (G) on carcass composition

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
Slaughter wt, kg	133.9	135.3	0.31	113.8[a]	135.8[b]	154.2[c]	<0.01	134.1	135.1	0.45	0.45	0.14	0.99	0.07
Hot carcass wt, kg	100.8	104.1	<0.01	85.4[a]	102.4[b]	119.6[c]	<0.01	101.8	103.0	0.24	0.20	0.94	0.95	0.79
Dressing %	75.4	77.0	0.18	75.1	75.4	78.1	0.09	76.0	76.4	0.74	0.96	0.29	0.98	0.15
Side wt, kg	50	49.4	0.08	41.2[a]	50[b]	57.9[c]	<0.01	49.6	49.7	0.83	0.17	0.78	0.40	0.89
10th rib backfat depth, mm	20.9	25.1	<0.01	19.9[a]	23.8[b]	25.3[b]	<0.01	25.1	20.9	<0.01	0.30	0.78	0.09	0.15
Last rib backfat depth, mm	23.7	26.9	<0.01	22.8[a]	25.4[b]	27.8[c]	<0.01	25.3	25.3	0.97	0.46	0.25	0.94	0.93
Loin eye area, cm^2	56.4	54.2	0.08	51.5[a]	54.8[b]	59.6[c]	<0.01	53.6	57.0	0.01	0.94	0.59	1.00	0.47
Carcass length (cm) from aitch bone to first rib	87.6	88.8	0.01	83.9[a]	88.4[b]	92.3[c]	<0.01	87.8	88.6	0.08	0.19	0.66	0.42	0.02
Carcass muscle score, USDA scale 1-3	2.7	2.5	<0.01	2.6	2.6	2.6	0.62	2.5	2.6	0.02	0.98	0.39	0.82	0.30
% Fat Free Lean*	54.3	52.0	<0.01	54.8[a]	52.7[b]	52.1[b]	<0.01	52.1	54.3	<0.01	0.38	0.98	0.41	0.59

* Calculated using the equation: (8.5876–(21.8957 x 10th rib fat, in) +(3.0047 X loin eye area, in.2) +(.4650 x hot carcass wt, lbs.)) / hot carcass wt * 100 (Griffin, 2011)

[a, b, c] Means differ (P<.05)

Table 3.3 Effect of sire line (S), weight end point (W), and gender (G) on carcass quality characteristics

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
pH – 1 h														
Longissimus dorsi	6.01	6.03	0.68	6.04	6.04	5.99	0.75	6.04	6.01	0.61	0.30	0.85	0.38	0.68
Semimembranosus	5.80	5.68	0.06	5.80	5.69	5.73	0.31	5.74	5.74	0.91	0.37	0.21	0.85	0.84
pHu														
Longissimus dorsi	5.53	5.53	0.90	5.55	5.53	5.51	0.61	5.53	5.53	0.88	0.36	0.07	0.61	0.73
Semimembranosus	5.77	5.70	0.14	5.76	5.73	5.73	0.80	5.74	5.74	0.94	0.82	0.05	0.69	0.94
NPPC Scores														
Color, Scale 1-6	3.0	2.9	0.39	2.8[a]	2.9[ab]	3.1[b]	0.04	2.9	2.9	0.77	0.72	0.02	0.46	0.04
Marbling, Scale 1-10	1.8	2.2	<0.01	1.9	2.0	2.0	0.29	2.1	1.8	0.01	0.21	0.47	0.91	0.97
Firmness, Scale 1-5	3.0	3.1	0.56	2.9	3.2	3.1	0.07	3.0	3.1	0.80	0.39	0.67	0.22	0.28
L*	55.3	55.1	0.82	55.8	54.9	54.9	0.37	55.4	54.9	0.37	0.42	0.79	0.81	0.17
a*	8.5	8.4	0.61	8.4	8.2	8.7	0.30	8.6	8.3	0.25	0.65	0.21	0.90	0.70
b*	16.4	16.6	0.49	16.5	16.4	16.6	0.70	16.8	16.1	0.01	0.45	0.51	0.17	0.09
% Drip loss	4.1	4.2	0.85	5.0	3.4	4.0	0.11	4.6	3.7	0.12	0.12	0.99	0.29	0.92

[a, b, c] Means differ (P<.05)

Table 3.4 Effect of sire line (S), weight endpoint (W), and gender (G) on ham quality for the gluteus medius and gluteus profundus

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
Gluteus medius														
pHu	5.60	5.56	0.10	5.60	5.60	5.56	0.27	5.58	5.59	0.83	0.58	0.42	0.32	0.05
L*	47.1	49.3	0.01	48.4	47.6	48.7	0.46	48.7	47.7	0.20	0.04	0.32	0.17	0.83
a*	10.3	10.0	0.39	9.9	10.3	10.2	0.55	10.1	10.2	0.75	0.48	0.67	0.30	0.97
b*	15.5	15.7	0.64	15.6	15.5	15.7	0.86	15.8	15.4	0.11	0.06	0.72	0.32	0.52
Gluteus profundus														
pHu	5.92	5.85	0.10	5.88	5.84	5.93	0.27	5.87	5.90	0.40	0.55	0.35	0.90	0.18
L*	37.8	40.0	0.03	39.2	39.3	38.2	0.60	40.1	37.8	0.03	0.06	0.27	0.06	0.70
a*	15.9	15.7	0.82	15.6	15.9	15.9	0.89	15.5	16.0	0.46	0.61	0.04	0.49	0.74
b*	16.7	16.7	0.93	17.1	16.6	16.4	0.27	17.0	16.3	0.06	0.48	0.12	0.69	0.61

Table 3.5 Effect of sire line (S), weight endpoint (W), and gender (G) on primal weights (kg) and their subprimals (kg)

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
Picnic	5.7	5.6	0.42	4.7[a]	5.5[b]	6.6[c]	<0.01	5.5	5.7	0.14	0.39	0.42	0.25	0.70
Boneless picnic	4.5	4.3	0.25	3.7[a]	4.3[b]	5.3[c]	<0.01	4.3	4.5	0.07	0.93	0.57	0.36	0.81
Boston	4.7	4.8	0.13	3.9[a]	4.9[b]	5.3[c]	<0.01	4.7	4.7	0.69	0.50	0.27	0.33	0.65
Boneless Boston	4.6	4.8	0.13	3.9[a]	4.9[b]	5.3[c]	<0.01	4.7	4.7	0.69	0.50	0.27	0.33	0.65
Belly	7.8	8.1	0.01	6.4[a]	8.1[b]	9.4[c]	<0.01	8.1	7.8	0.06	0.68	0.18	0.97	0.50
Belly, skinless	7.0	7.3	0.01	5.7[a]	7.2[b]	8.4[c]	<0.01	7.2	7.0	0.03	0.65	0.08	0.96	0.56
Sparerib	1.8	1.9	0.67	1.5[a]	1.9[b]	2.1[c]	<0.01	1.8	1.9	0.29	0.36	0.67	0.10	0.72
Loin	10.6	10.5	0.37	8.9[a]	10.5[b]	12.2[c]	<0.01	10.3	10.7	<0.01	0.33	0.24	0.65	0.23
Boneless loin	4.1	3.9	0.12	3.5[a]	3.9[b]	4.7[c]	<0.01	3.9	4.1	0.14	0.13	0.27	0.53	0.09
Tender	0.63	0.62	0.28	0.53[a]	0.63[b]	0.72[c]	<0.01	0.60	0.65	<0.01	0.95	0.98	0.25	0.55
Boneless sirloin	1.4	1.1	0.27	1.3	1.1	1.3	0.83	1.1	1.4	0.23	0.34	0.32	0.37	0.51
Ham	12.0	11.9	0.44	13.9[a]	11.8[b]	10.2[c]	<0.01	11.9	12.1	0.03	0.04	0.81	0.63	0.35
Skinless ham	11.4	11.2	0.24	9.6[a]	11.2[b]	13.2[c]	<0.01	11.2	11.4	0.03	0.05	0.83	0.40	0.29
Inside	2.4	2.3	0.02	2.1[a]	2.4[b]	2.7[c]	<0.01	2.3	2.4	<0.01	0.95	0.63	<0.01	0.67
Outside	2.6	2.6	0.63	2.3[a]	2.6[b]	3.0[c]	<0.01	2.5	2.7	<0.01	0.29	0.97	0.41	0.63
Knuckle	1.6	1.4	<0.01	1.3[a]	1.5[b]	1.7[c]	<0.01	1.5	1.5	0.19	0.02	0.77	0.36	0.25
Boneless cut yield (6 mm trim)	41.0	40.2	0.19	34.7[a]	40.2[b]	47.0[c]	<0.01	39.8	41.4	<0.01	0.38	0.61	0.50	0.62

[a, b, c] Means differ (P<.05)

Table 3.6 Effect of sire line (S), weight endpoint (W), and gender (G) on primals and their subprimals as a percentage of side weight

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
%Picnic	11.5	11.1	0.16	11.5	11.4	11.1	0.36	11.2	11.5	0.28	0.39	0.37	0.19	0.51
%Boneless picnic	9.1	8.7	0.11	8.9	8.6	9.1	0.24	11.2	11.5	0.12	0.76	0.55	0.37	0.79
%Boston	9.4	9.6	0.35	9.5 [a]	9.9[b]	9.2[a]	0.02	9.5	9.6	0.62	0.88	0.18	0.47	0.64
% Boneless Boston	6.8	7.2	0.02	7.0	7.1	6.8	0.21	6.9	7.1	0.36	0.52	0.39	0.06	0.94
%Belly	15.8	16.2	0.06	15.7	16.2	16.2	0.13	16.3	15.7	0.03	0.44	0.20	0.41	0.50
%Belly, skinless	14.1	14.5	0.05	13.9[a]	14.5[b]	14.5[b]	0.05	14.6	14.0	0.01	0.32	0.07	0.39	0.55
%Spararib	3.7	3.7	0.87	3.6	3.8	3.7	0.23	3.7	3.7	0.43	0.35	0.60	0.09	0.73
%Loin	21.5	21	0.02	21.7[a]	21.0[b]	21.0[b]	0.02	20.8	21.7	<0.01	0.37	0.05	0.77	0.13
% Boneless loin	8.4	7.8	0.03	8.5[a]	7.8[b]	8.0[ab]	0.06	8.0	8.2	0.20	0.14	0.15	0.42	0.10
%Tender	1.3	1.2	0.06	1.3	1.3	1.2	0.34	1.2	1.3	<0.01	0.92	0.82	0.11	0.51
% Boneless sirloin	2.9	2.2	0.26	3.2	2.3	2.2	0.26	2.2	2.9	0.25	0.36	0.34	0.38	0.49
%Ham	24.4	23.9	0.01	24.7[a]	24.1[b]	23.8[c]	<0.01	24.0	24.4	0.03	0.11	0.88	0.23	0.11
%Ham, skinless	23.1	22.5	<0.01	23.2[a]	22.4[b]	22.8[ab]	0.01	22.6	23.0	0.04	0.14	0.83	0.08	0.06
%Ham, inside	4.9	4.7	<0.01	5.0[a]	4.8[b]	4.7[b]	<0.01	4.7	4.9	0.01	0.93	0.65	0.01	0.53
%Ham, outside	5.3	5.2	0.20	5.5[a]	5.1[b]	5.2[b]	<0.01	5.1	5.4	<0.01	0.50	0.86	0.33	0.56
%Knuckle	3.2	2.9	<0.01	3.2[a]	3.0[ab]	2.9[b]	0.03	3.0	3.1	0.24	0.03	0.74	0.40	0.16
% Boneless cuts	37.7	36.5	<0.01	38.0[a]	36.8[b]	36.5[b]	<0.01	36.5	37.8	<0.01	0.69	0.42	0.35	0.52

[a, b, c] Means differ (P<.05)

Table 3.7 Effect of sire line (W), weight endpoint (W), and gender (G) on length, thickness, and firmness of the belly

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
Length, cm	73.1	73.7	0.40	70.7[a]	73.5[b]	76.0[c]	<0.01	73.3	73.5	0.75	0.84	0.06	0.24	0.21
Width, cm	28.0	27.9	0.63	26.2[a]	27.9[b]	30.0[c]	<0.01	27.5	28.4	0.04	0.27	0.93	0.47	0.11
Thickness														
Cranial, cm	4.7	4.6	0.80	4.2[a]	4.7[ab]	5.1[b]	0.01	4.8	4.6	0.34	0.69	0.62	0.89	0.82
0.25, cm	3.2	3.4	0.23	2.9[a]	3.4[b]	3.6[b]	<0.01	3.4	3.2	0.23	0.44	0.64	0.55	0.36
0.5, cm	2.3	2.5	0.07	2.2[a]	2.4[a]	2.7[b]	<0.01	2.6	2.3	0.01	0.61	0.98	0.28	0.47
0.75, cm	2.9	3.2	0.16	2.7[a]	3.0[ab]	3.4[b]	0.01	3.2	2.9	0.08	0.90	0.33	0.10	0.34
Caudal, cm	4.0	4.5	0.03	3.9[a]	4.3[ab]	4.5[b]	0.05	4.5	4.0	0.02	0.64	0.97	0.62	0.65
Average	3.4	3.6	0.09	3.2[a]	3.6[b]	3.9[c]	<0.01	3.7	3.4	0.02	0.52	0.91	0.37	0.46
Firmness														
Dorsal, cm	15.2	14.5	0.60	13.0	15.5	16.0	0.18	16.2	13.5	0.05	0.86	0.76	0.68	0.47
Ventral, cm	17.6	17.1	0.73	17.4	15.9	18.9	0.24	17.6	17.2	0.75	0.32	0.57	0.23	0.70

[a, b, c] Means differ (P<.05)

Table 3.8 Effect of sire line (S), weight endpoint (W), and gender (G) on proximate composition of longissimus trimmed of all external fat

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
Moisture	73.0	72.7	0.28	73.3	72.8	72.6	0.15	72.7	73.1	0.10	0.88	0.93	0.32	0.73
Crude protein	23.9	24.0	0.51	23.9	24.0	24.1	0.70	23.9	24.0	0.62	0.22	0.22	0.80	0.17
Crude fat	2.4	3.2	<0.01	2.5	3.0	3.0	0.08	3.2	2.4	<0.01	0.25	0.55	0.59	0.36

Table 3.9 Effect of sire line (S), weight endpoint (W), and gender (G) on Warner-Bratzler shear force (WBSF)

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
Cook time, min	6.1	6.0	0.87	6.1[ab]	5.6[a]	6.5[b]	0.01	6.2	5.9	0.21	0.71	0.83	0.54	0.92
Thaw loss, %	6.5	6.4	0.71	6.7[ab]	6.9[a]	5.8[b]	0.05	6.4	6.5	0.64	0.99	0.22	0.74	0.82
Cook loss, %	12.4	12.2	0.85	12.5	11.8	12.7	0.54	12.8	11.9	0.20	0.66	0.66	0.20	0.21
Total loss, %	18.1	17.9	0.71	18.4	17.9	17.7	0.71	18.3	17.6	0.29	0.60	0.27	0.26	0.24
Final temperature, °C	67.8	67.9	0.92	68.0	68.0	67.6	0.80	67.9	67.8	0.81	0.72	0.75	0.98	0.52
Degree of doneness	3.9	3.6	0.16	70.7	73.4	76.0	0.92	3.7	3.7	0.93	0.01	0.78	0.12	<0.01
WBSF, kg	2.9	2.7	0.36	2.8	2.8	2.9	0.37	2.8	2.9	0.35	0.56	0.29	0.54	0.32

[a, b, c] Means differ (P<.05)

Table 3.10 Effect of sire line (S), weight endpoint (W), and gender (G) on slice shear force (SSF)

Variable	Sire line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*W	S*G	W*G	S*W*G
Cook time, min	5.6	5.5	0.69	5.3 [a]	5.1 [a]	6.1 [b]	<0.01	5.6	5.5	0.68	0.22	0.27	0.70	0.34
Thaw loss, %	7.4	6.9	0.22	7.5	7.5	6.5	0.13	7.4	6.9	0.22	0.06	0.62	0.83	0.27
Cook loss, %	12.1	12.2	0.96	11.9	12.0	12.6	0.60	12.1	12.2	0.89	0.40	0.68	0.29	0.61
Total loss, %	18.7	18.2	0.52	18.5	18.6	18.3	0.97	18.7	18.3	0.57	0.72	0.95	0.57	0.51
Final temperature, °C	69.2	68.6	0.38	69	68.9	68.8	0.95	69.0	68.8	0.88	0.32	0.05	0.88	0.06
Degree of doneness	4.3	3.6	<0.01	3.8 [a]	3.7 [a]	4.3 [b]	0.05	3.9	4.0	0.50	0.07	0.61	0.85	0.24
SSF, kg	14.0	15.4	0.01	15.1	13.9	15.0	0.08	14.5	14.8	0.63	0.18	0.77	0.68	0.51

[a, b, c] Means differ (P<.05)

3.11 Interaction of sire line and gender for loin color, a* of the Gluteus profundus, loin as a % of side weight, and slice shear force final temperature

Variable	LYL F	LYL M	MQL F	MQL M
NPPC loin color score	3.07[a]	2.86[ab]	2.75[b]	3.01[ab]
a* Gluteus profundus	15.44[ab]	16.28[ab]	16.60[a]	14.83[b]
% Loin	21.73[a]	21.32[a]	21.64[a]	20.29[b]
Slice shear force final temperature	69.9[a]	68.6[ab]	67.8[b]	69.4[ab]

[a, b,] Means differ (P<.05)

Table 3.12 Interaction of gender and weight endpoint for inside ham weight and inside ham as a percentage of side weight

Variable	113 F	136 F	159 F	113 M	136 M	159 M
Inside ham, kg	2.11[d]	2.36[c]	2.87[a]	2.01[d]	2.40[c]	2.57[b]
% Inside ham	5.07[a]	4.73[b]	4.97[ab]	4.94[ab]	4.78[b]	4.43[c]

[a, b, c, d] Means differ (P<.05)

Table 3.13 Interaction of sire line and weight endpoint for L* gluteus medius, knuckle weight, knuckle as a percentage of side weight, and Warner-Bratzler shear force degree of doneness

Variable	LYL 113 kg	LYL 136 kg	LYL 159 kg	MQL 113 kg	MQL 136 kg	MQL 159 kg
L* Gluteus medius	47.49^{bc}	47.58^{bc}	46.33^{c}	49.24^{ab}	47.57^{bc}	51.15^{a}
Skinless ham, kg	9.70^{c}	11.41^{b}	13.05^{a}	9.41^{c}	11.01^{b}	13.31^{a}
Knuckle, kg	1.40^{b}	1.62^{a}	1.70^{a}	1.23^{c}	1.39^{b}	1.72^{a}
% Knuckle	3.40^{a}	3.27^{a}	2.97^{b}	3.0^{b}	2.76^{b}	2.94^{b}
Warner-Bratzler degree of doneness	4.16^{a}	4.0^{ab}	4.10^{ab}	3.27^{c}	3.44^{bc}	4.10^{ab}

$^{a, b, c}$ Means differ (P<.05)

Table 3.14 Interaction of sire line, weight end point, and gender on carcass length, NPPC loin color score, gluteus medius pH, and Warner-Bratzler shear force degree of doneness

Variable	LYL F 113 kg	LYL F 136 kg	LYL F 159 kg	MQL F 113 kg	MQL F 136 kg	MQL F 159 kg	LYL M 113 kg	LYL M 136 kg	LYL M 159 kg	MQL M 113 kg	MQL M 136 kg	MQL M 159 kg
Carcass length, cm	83.64^{hg}	88.62^{de}	92.06^{bc}	85.29^{fg}	89.40^{d}	92.61^{ab}	83.92^{hg}	87.03^{fe}	90.49^{dc}	82.67^{h}	88.63^{de}	94.26^{a}
NPPC loin color	3.11^{ab}	3.05^{abc}	3.05^{abc}	2.61^{cd}	2.66^{bcd}	2.99^{abc}	2.44^{d}	2.88^{abcd}	3.27^{a}	2.99^{abc}	2.99^{abc}	3.05^{abc}
Gluteus medius pH	5.58^{abc}	5.64^{ab}	5.63^{ab}	5.57^{abc}	5.57^{abc}	5.55^{bc}	5.69^{a}	5.58^{abc}	5.51^{c}	5.55^{bc}	5.60^{abc}	5.56^{bc}
Warner-Bratzler shear degree of doneness	3.55^{cd}	4.44^{abc}	3.55^{cd}	3.66^{bcd}	3.55^{cd}	3.66^{bcd}	4.77^{a}	3.55^{cd}	3.44^{d}	2.88^{d}	3.33^{d}	4.55^{ab}

$^{a, b, c, d, e, f, g, h}$ Means differ (P<.05)

CHAPTER 4

CONCLUSIONS

The rise in demand for pork in the foodservice industry has caused an increase for higher quality that attributes to an overall better experience as flavor, juiciness, and tenderness are maximized. In addition, producing the highest quantity of muscle tissue has been a goal for the industry for a long time, and merit buying programs have increased the desire for producers to raise these type of animals. This has led to a need for research in production animals that have the genetic propensity to produce these type of carcasses uniformly in production.

While the priority placed on desired leanness is often associated with a reduced eating quality, this study found very little differences in quality for the lean yield line (LYL) and the meat quality line (MQL). No quality differences were found as carcass weight increased; however the MQL carcasses had higher marbling scores than the LYL. Tenderness scores for both lines were below the threshold to be considered "tough," but the LYL had color advantages over the MQL. Advantages in meat quality were not as consistent across sire lines as were advantages in yield. More research targeting quality attributes of pork and consumer satisfaction should be done to determine which quality traits should be the focus of the selection programs in the U.S. swine industry.

Consistent advantages in lean yield existed in the LYL compared to the MQL. Increasing slaughter weight increased the pounds of boneless cuts; however, due to fat accumulation, increasing slaughter weight negatively impacted lean yield for both lines. However, neither sire lines averaged excessively high amounts of backfat. Significant yield and quality differences

were seen in barrows vs gilts, suggesting that perhaps further research might be needed in seeing how segregated feeding during production could increase profits by targeting them at two different markets. While this data provides insight for these two lines and what happens when their slaughter weights increase, more research needs to be done to shed light on the consistency of sire lines across generations and improvements made with both quality and yield characteristics.